Terrestrial-Glacier-Ocean Interaction

Why we know so little (do we?) and what (I think) we really need to know

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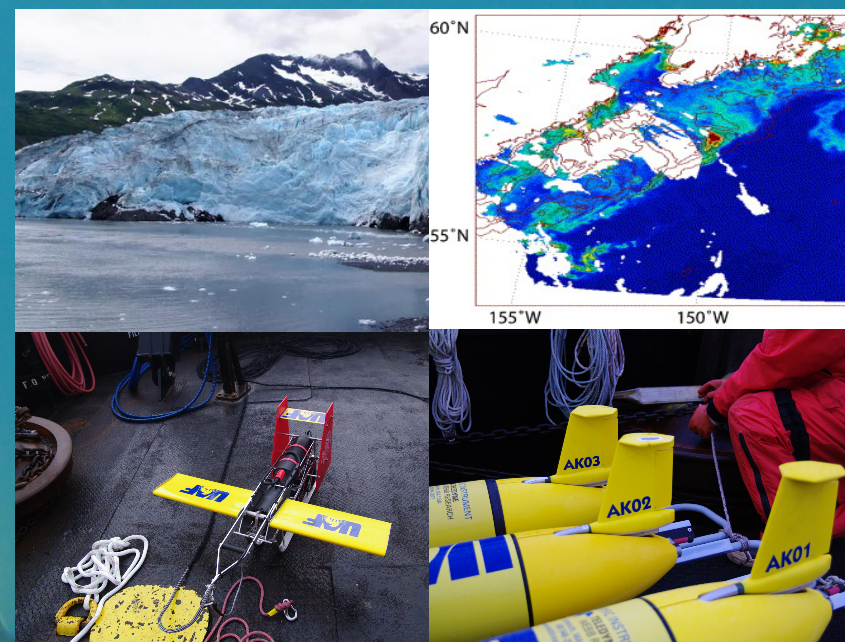


Juneau Glacier Workshop
March 2013

Outline

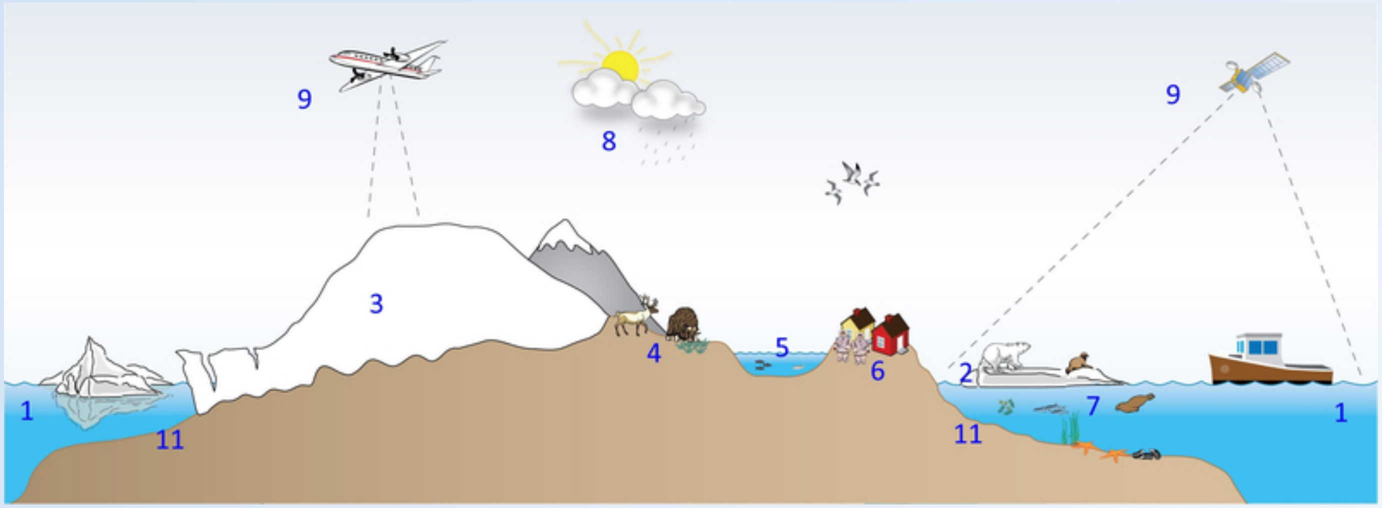
→Examples of terrestrial-glacier-ocean connections

→The spatial cascade: large-scale, shelf-scale, estuary/fjord connections
The temporal mess: PDO/AO, interannual variability, tidal cycles

→Physical-Biological connections: coastal mountains, runoff, ocean productivity

→How can we understand this system → how do we sample this system?

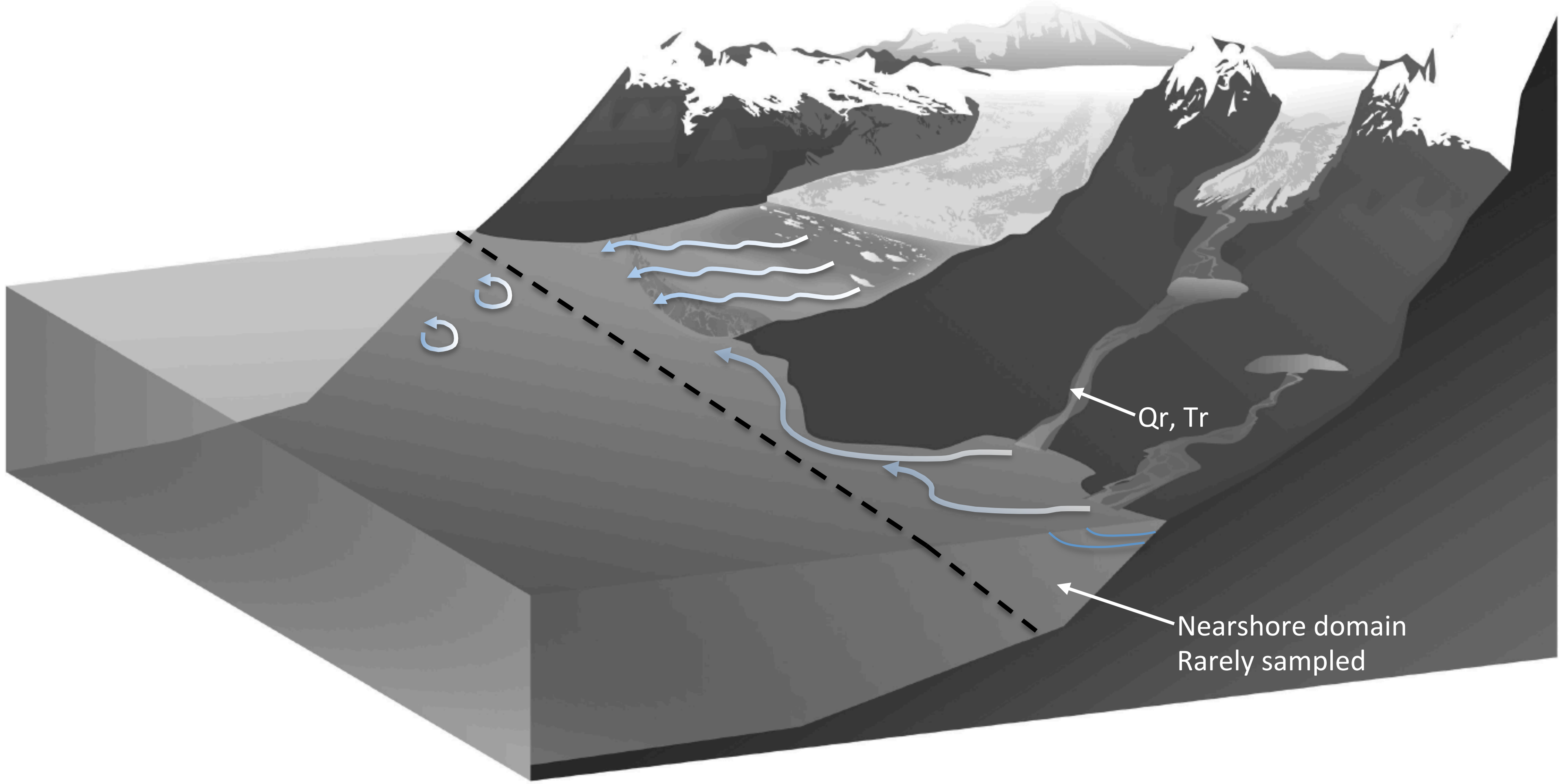
Greenland Climate Research Centre



1. Ocean and fjord systems
2. Sea ice
3. Ice sheet and glaciers
4. Terrestic eco systems
5. Limnic ecosystems
6. Society relations
7. Marine eco systems
8. Weather, climate and atmosphere
9. Surveillance
10. Data/models
11. Seabed history

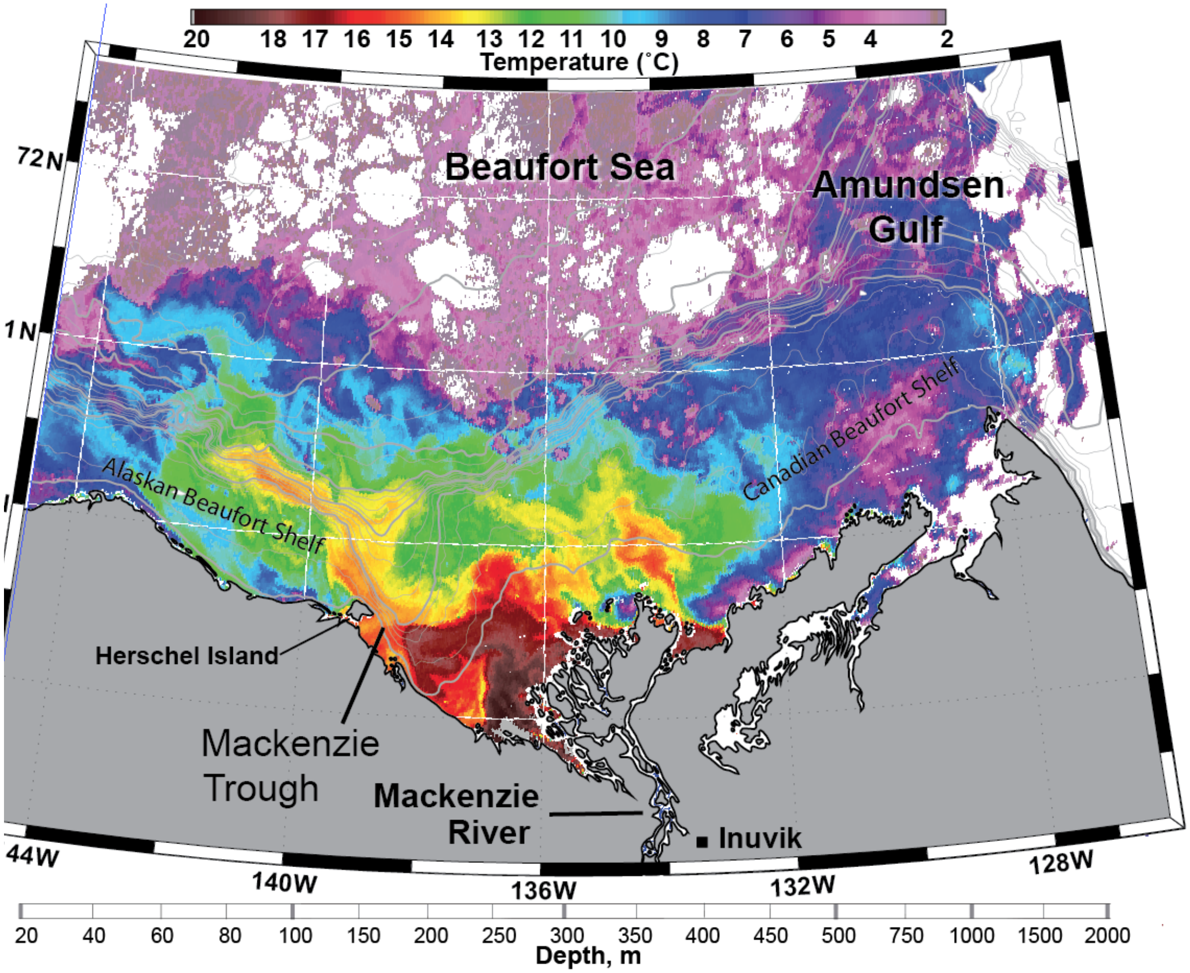
NOAA – Gulf of Alaska Large marine ecosystem

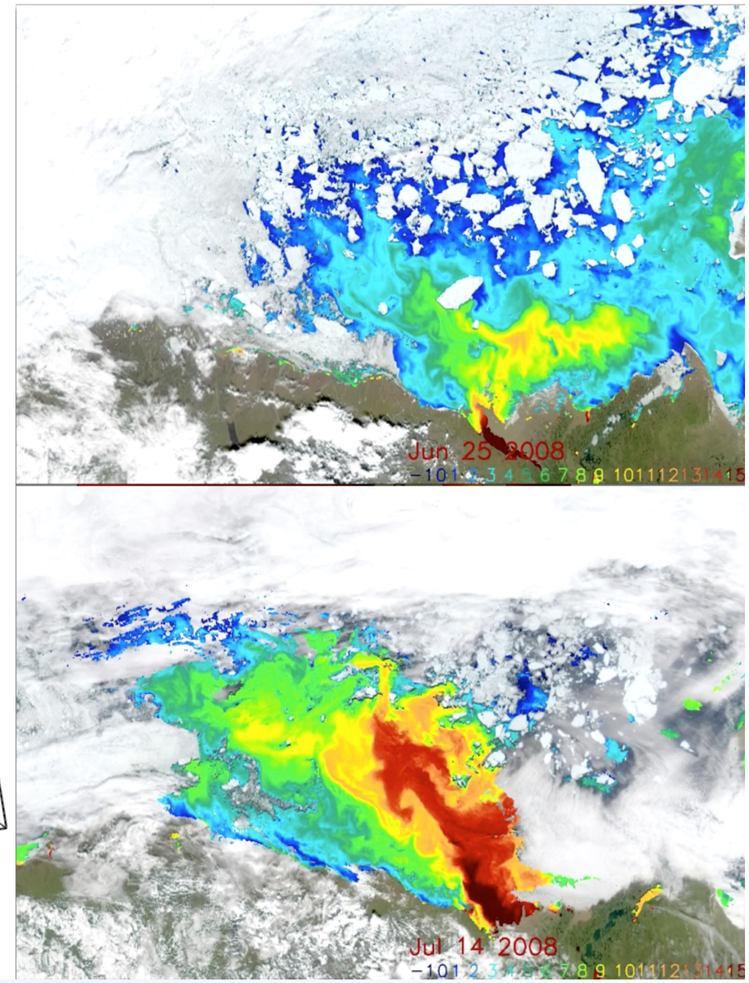
NOAA LME's: Five information modules – biological productivity, fish and fisheries, pollution and health, socioeconomics, and governance



The scales of the nearshore oceans (estuaries, fjords, coastlines) are small and typically not resolved by satellites, models *or* observations - this includes horizontal scales (~1 km or less), vertical scales (~1 m), and temporal scales (hourly to interannual).

Much of the oceanic heat and freshwater content are dominant in the very upper part of the ocean, typically top 5-50 m! Very challenging to sample properly.





AVHRR satellite image from July 2009 of the Mackenzie River delta, Alaskan and Canadian Beaufort shelves and the interior Beaufort Sea. Colors show sea surface temperature (SST) where purple and white is sea ice. Bathymetry contours are in gray.

Evolution of the Mackenzie Plume over a 20-day period from June 25 – July 14 2008 from AVHRR SST imagery.

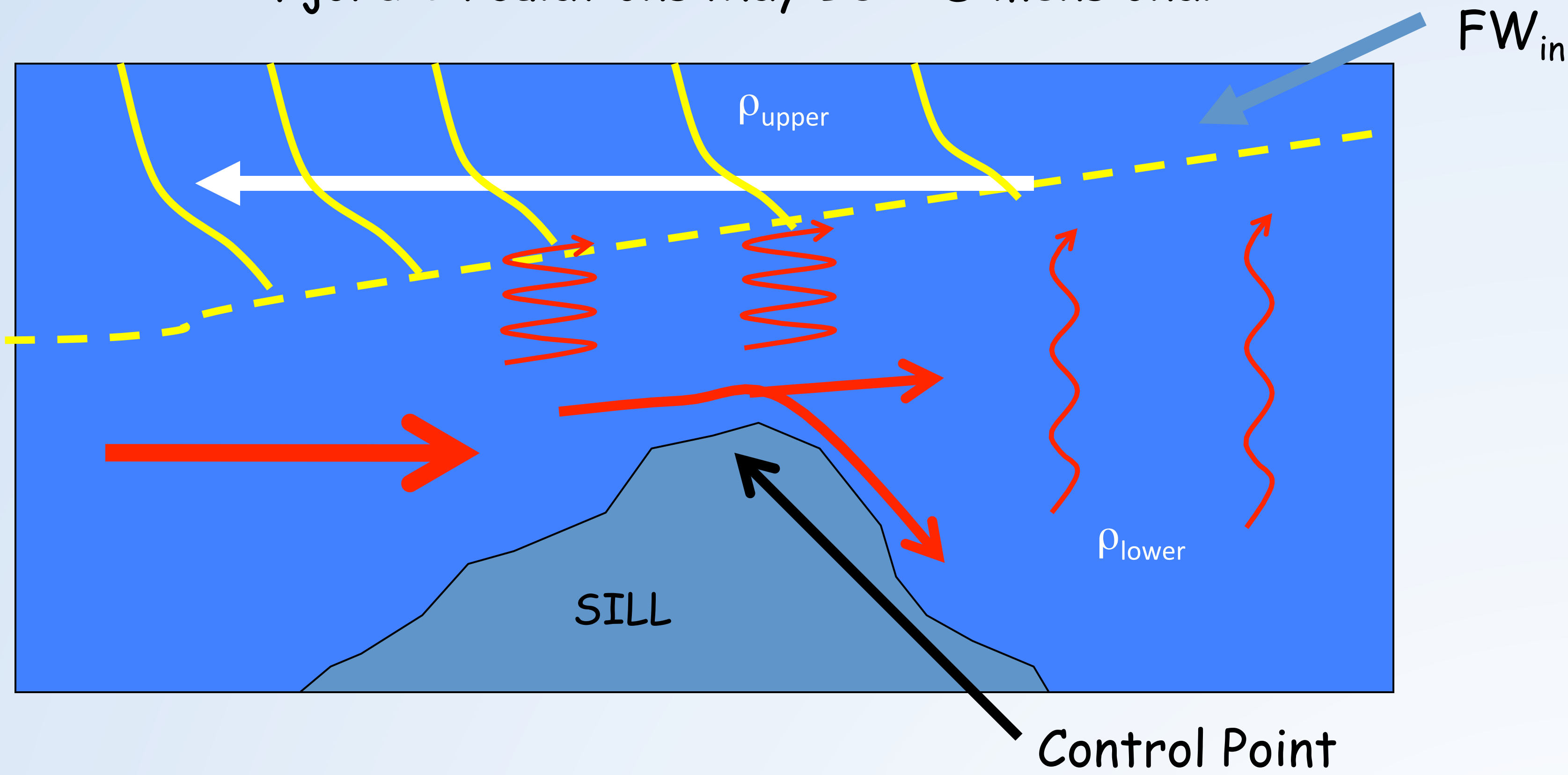
Dominant Time/Space scales and observation types

Time/ Length	< tidal (0.5 – 24 hrs)	Synoptic (2 – 15 days)	Monthly	Seasonal	Annual Cycle	Interannual (> 2 years)
< 10 km	Moorings Gliders, Towed body HFR, Drifters	Moorings Gliders, Towed body HFR, Drifters	Moorings Gliders HFR, Drifters	Moorings Gliders HFR, Drifters	Moorings	Moorings HFR CTD surveys
10 – 150 km	Moorings Gliders, Towed body HFR, Drifters	Moorings Gliders, Towed Body, HFR, Drifters, CTDs	Moorings Gliders, HFR, Drifters, CTDs	Moorings Gliders, HFR, Drifters, CTDs	Moorings	Moorings HFR, CTDs
>150 km	Moorings Gliders, Towed Body, HFR, Drifters	Towed Body	Gliders	Gliders	Moorings	Moorings HFR, CTDs

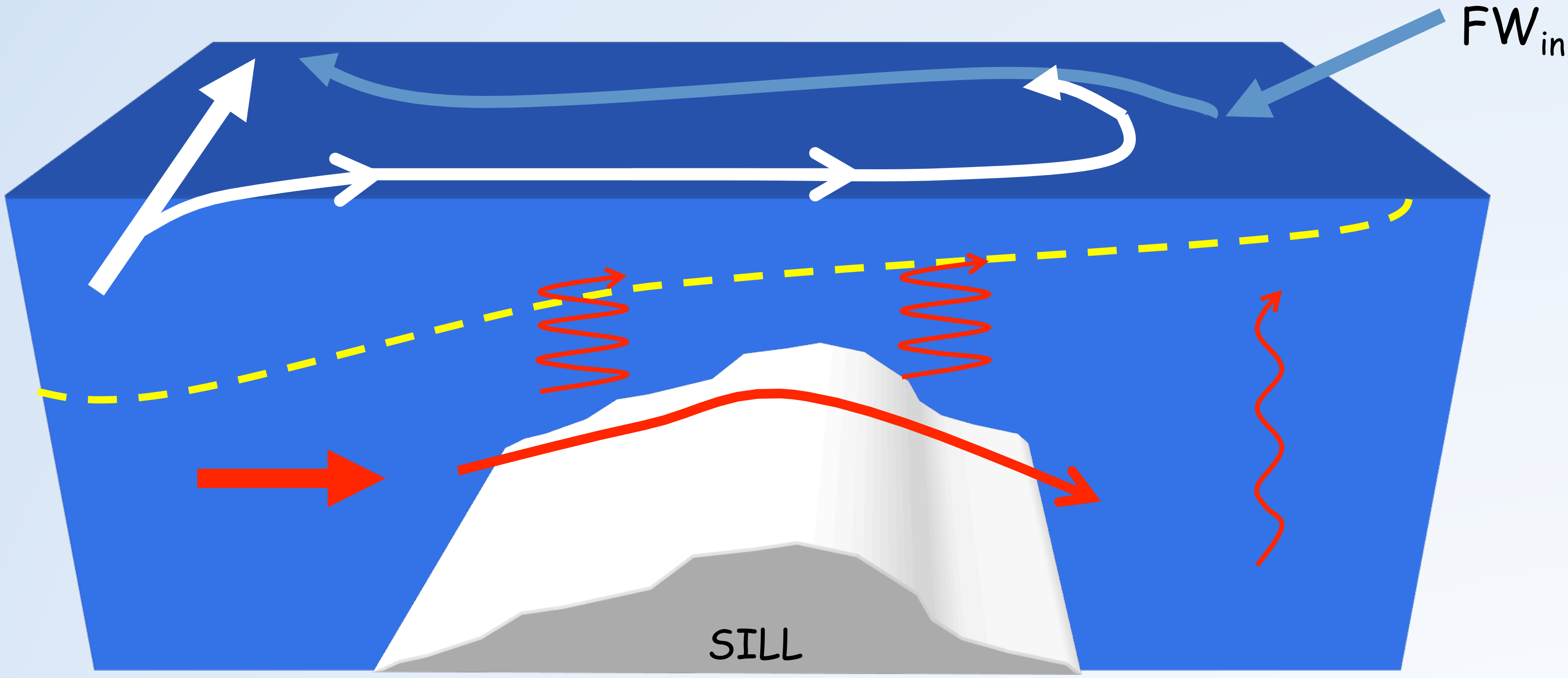
<1 km & min to hrs (and longer)
AUVs, towed vehicles and drifters

Red color = real time data

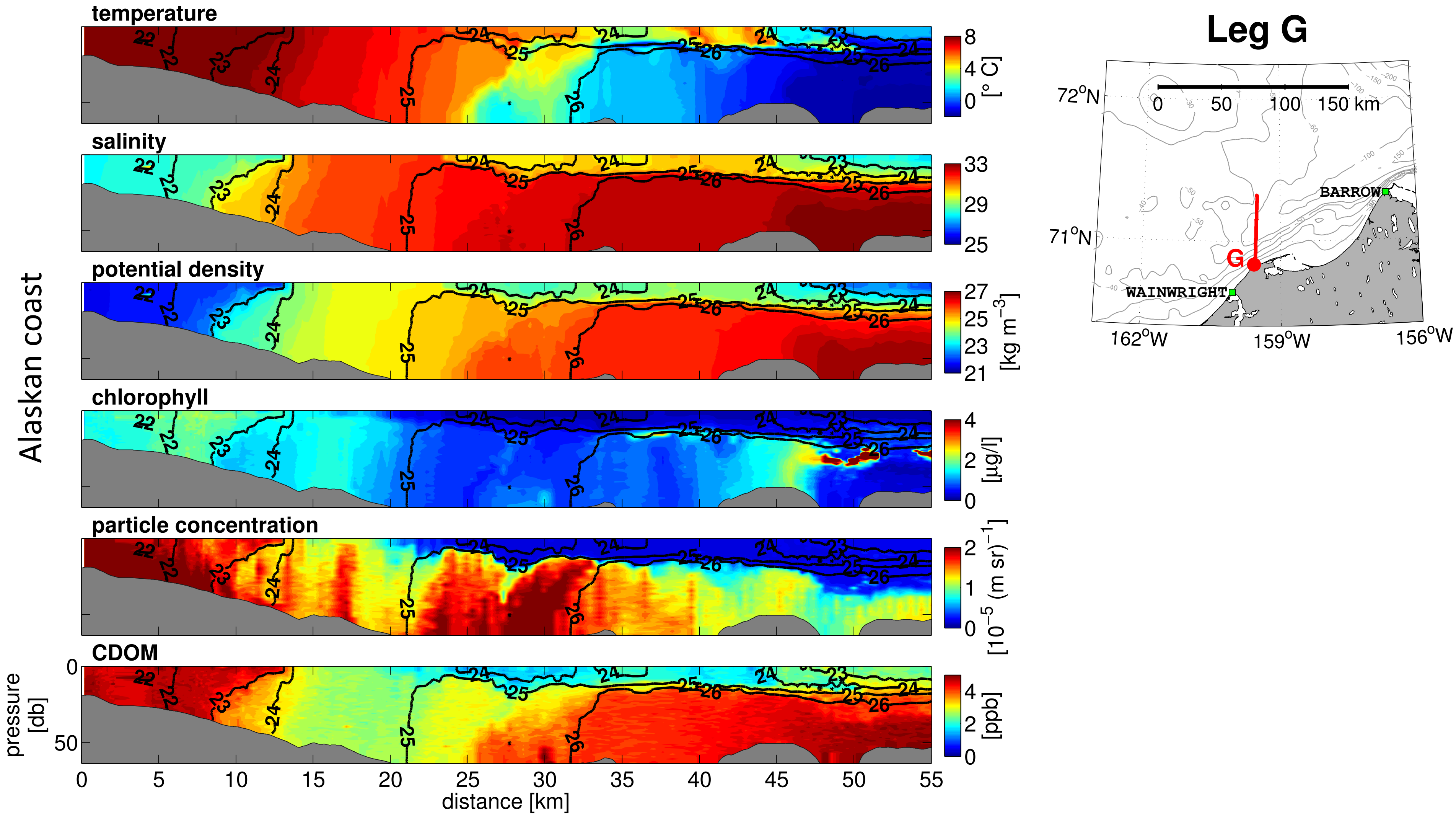
Fjord Circulations May Be 2-Dimensional



Or 3-Dimensional

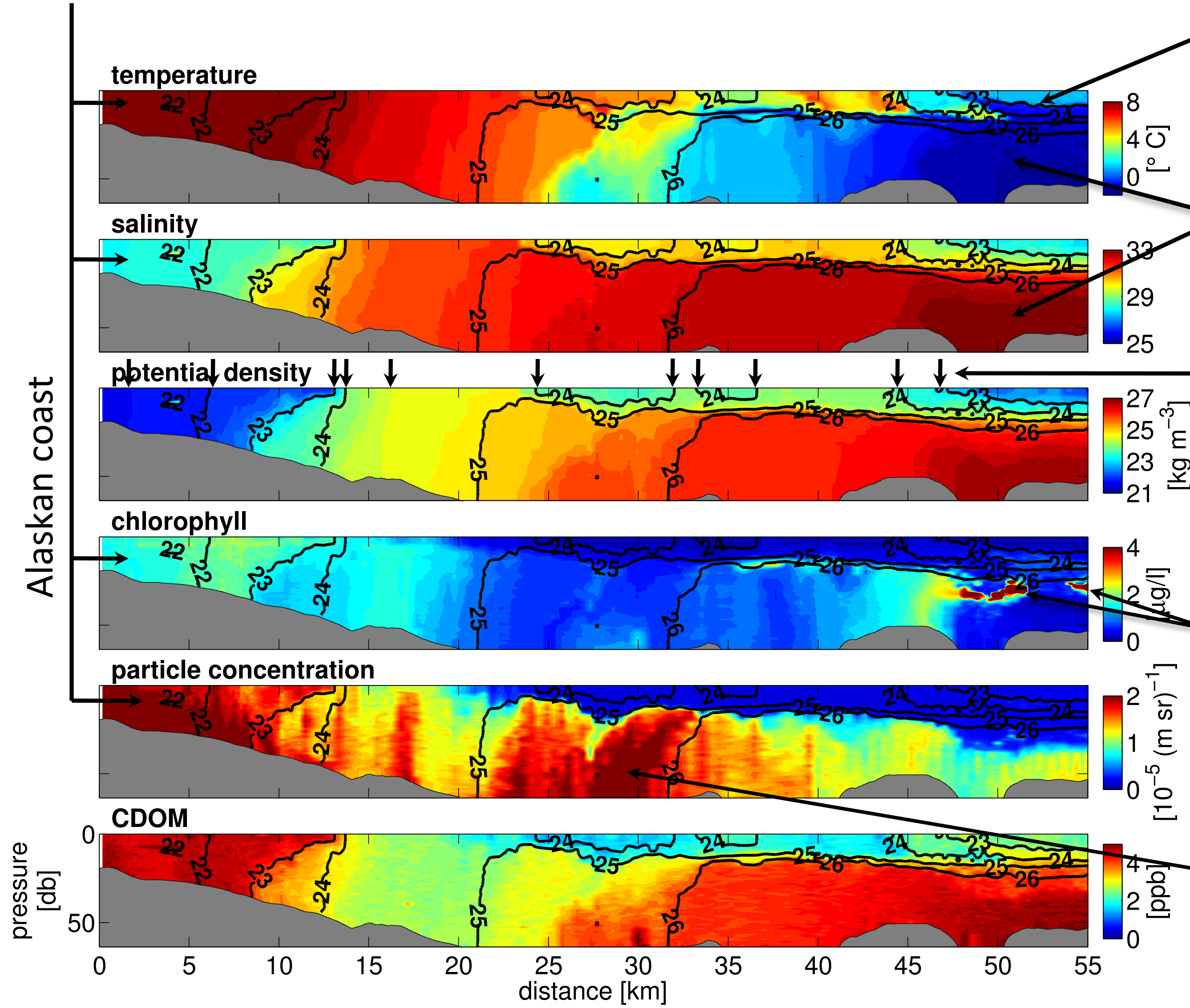


55-km Acrobat cross section across the mouth of Barrow Canyon



This section consists of over 125 vertical profiles from the Acrobat vehicle sampled over a 5-hour period

Nearshore domain <15 m depth,
rarely sampled. Mayor pathway for e.g. fry and returning mature salmon



Cold and fresh surface layer from ice melt

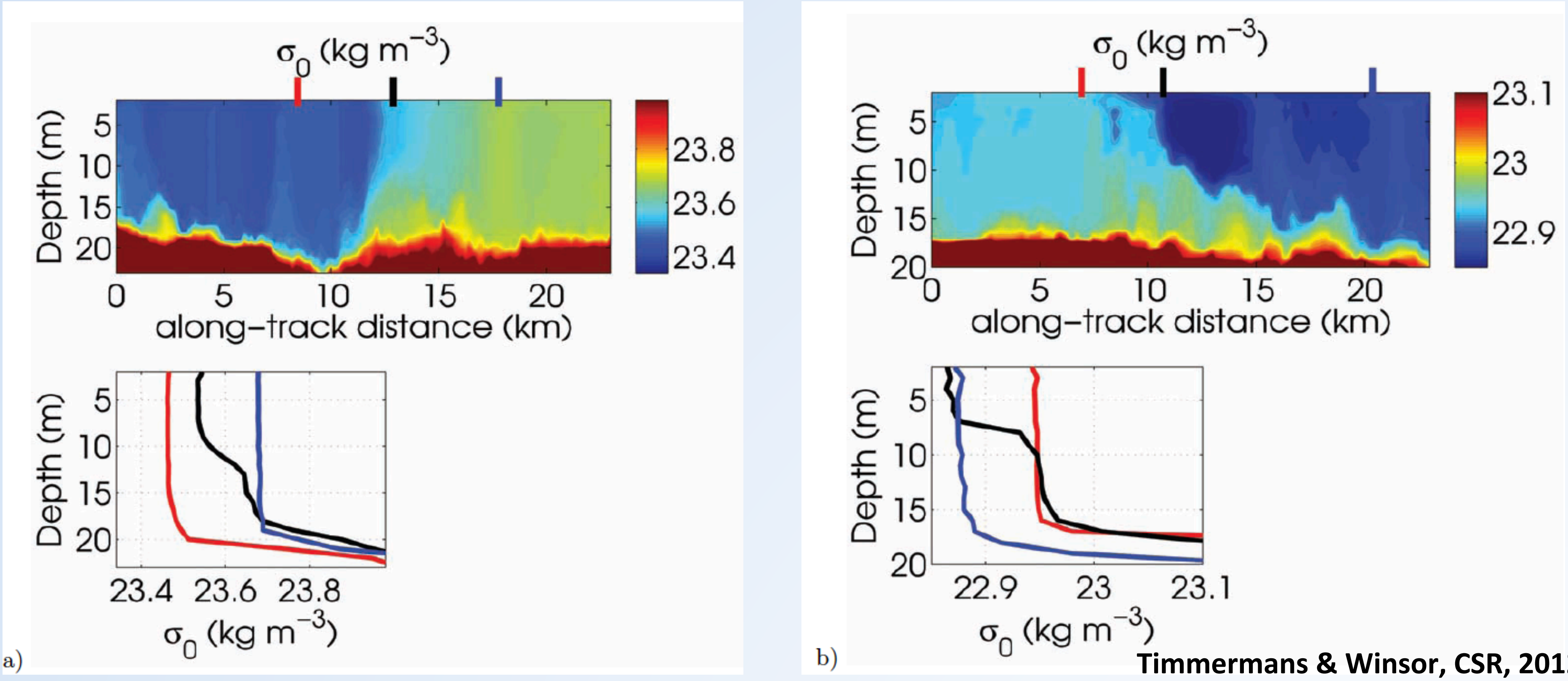
Winter water or “cold pool”

Multiple horizontal density fronts

Patchy chl max. associated with top of cold pool and “downdraft” at front

Strong flow with large re-suspended sediment concentrations

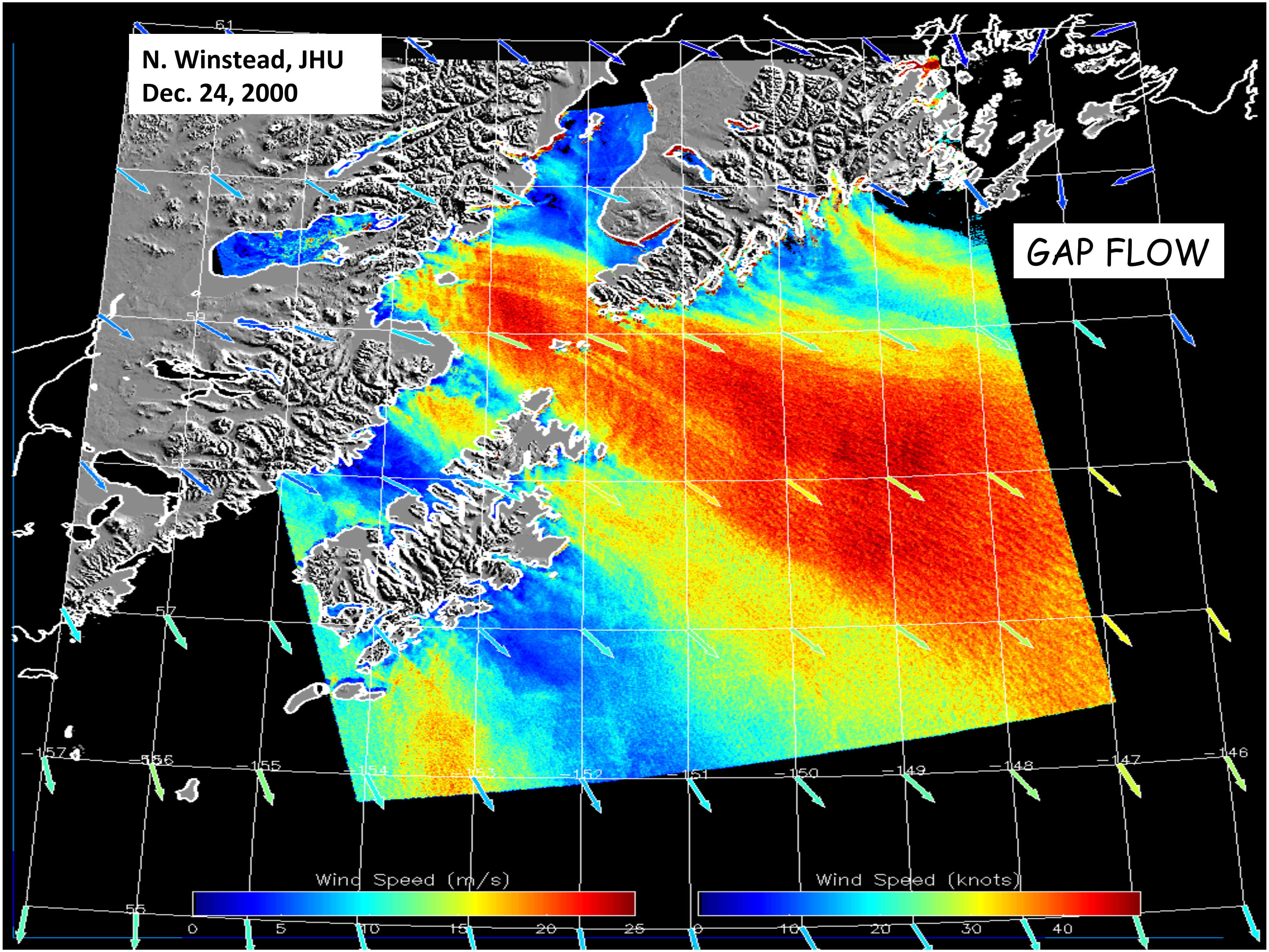
Freshwater from creeks, rivers, glaciers and in situ ice melt create ocean fronts

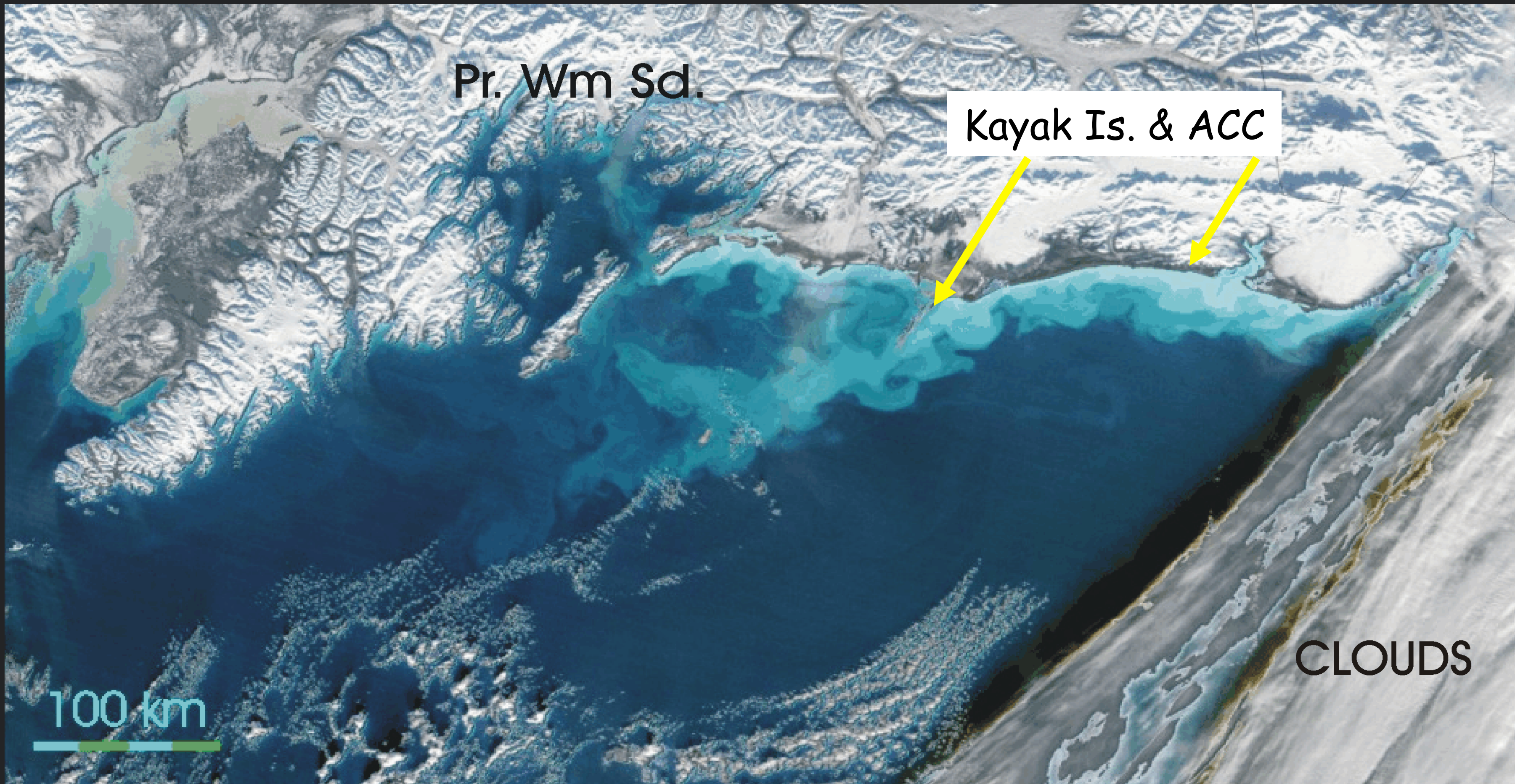


Timmermans & Winsor, CSR, 2012

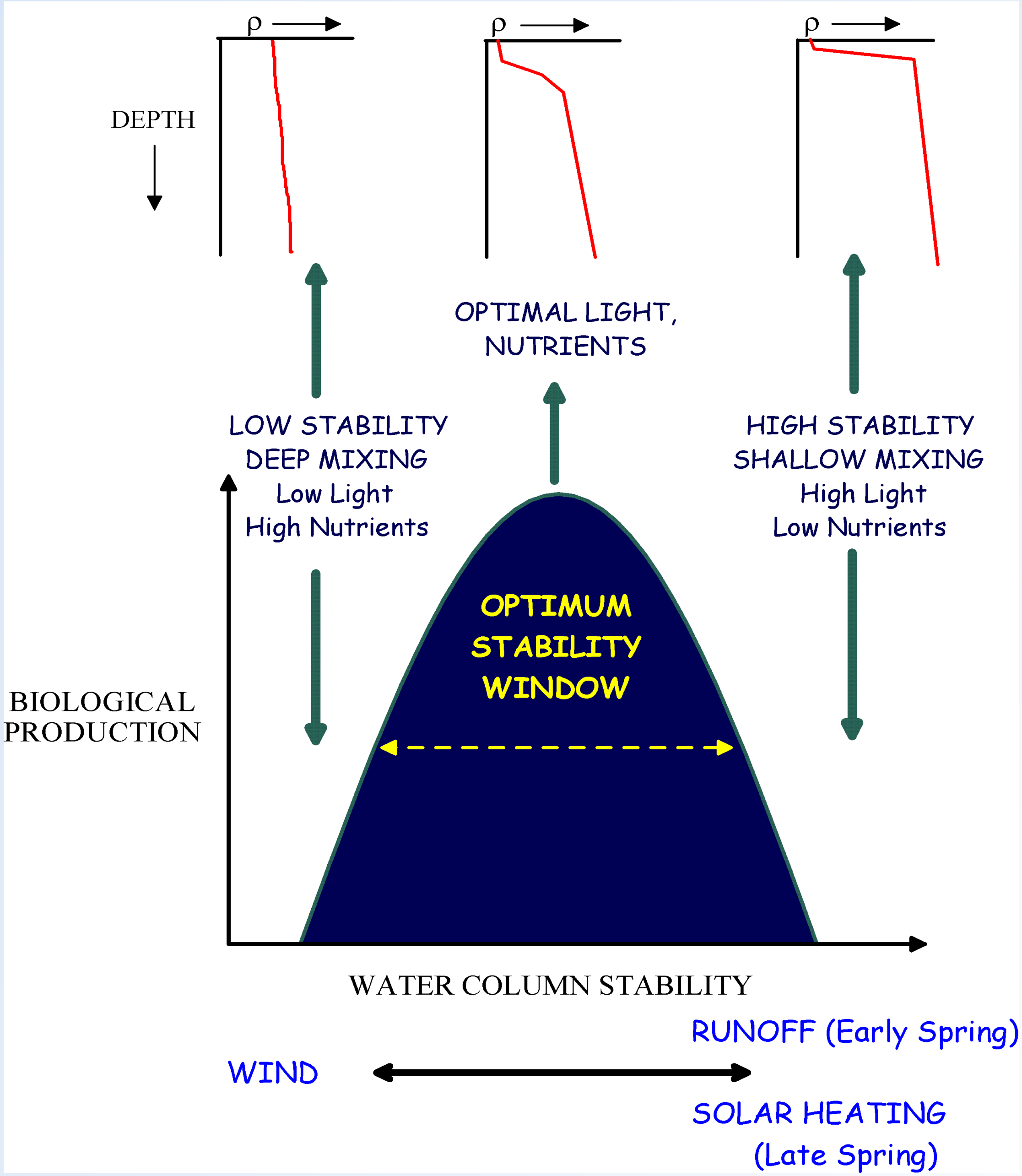
The observed sub-mesoscale horizontal density fronts play a role in setting surface-layer properties by restratifying the mixed layer. This restratication opposes processes (e.g. buoyancy fluxes and winds) that vertically mix the surface ocean.

AUVs &Towed vehicles observations enable us to observe these processes due to the high (~250 m) horizontal resolution. Important for biology (plankton, fish, seals, whales) and physical processes (mixing, advection, oil spill trajectories) etc.

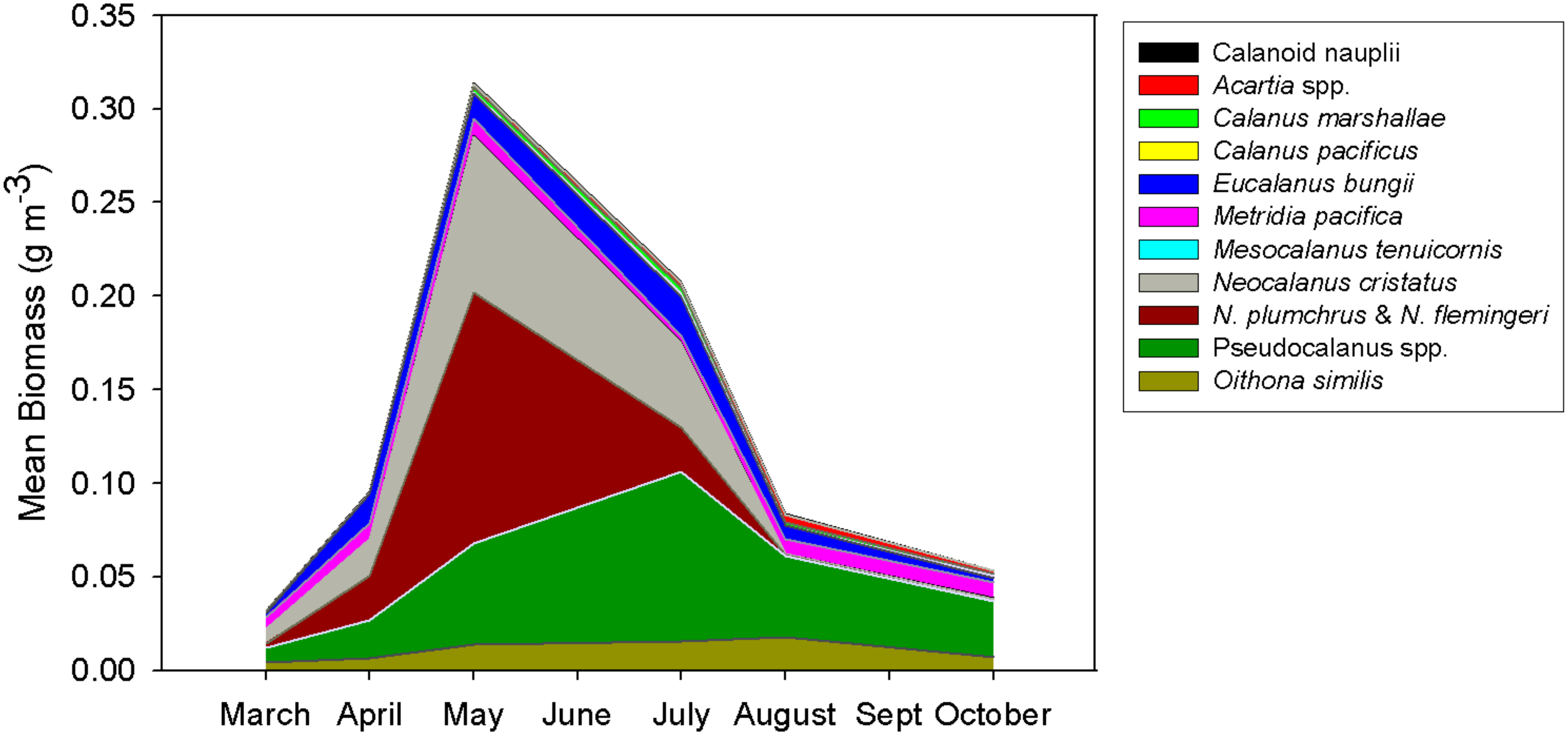

N. Winstead, JHU
Dec. 24, 2000
GAP FLOW
Wind Speed (m/s)
0 5 10 15 20 25
Wind Speed (knots)
0 10 20 30 40
61
60
59
58
57
56
−157
−156
−155
−154
−153
−152
−151
−150
−149
−148
−147
−146



MODIS, Nov. 7, 2001


ρ
ρ
ρ
DEPTH
OPTIMAL LIGHT,
NUTRIENTS
LOW STABILITY
DEEP MIXING
Low Light
High Nutrients
HIGH STABILITY
SHALLOW MIXING
High Light
Low Nutrients
OPTIMUM
STABILITY
WINDOW
BIOLOGICAL
PRODUCTION
WATER COLUMN STABILITY
RUNOFF (Early Spring)
WIND
SOLAR HEATING
(Late Spring)

Annual Cycle in Biomass of Major Calanoids
(Spring/early summer juvenile salmon food)

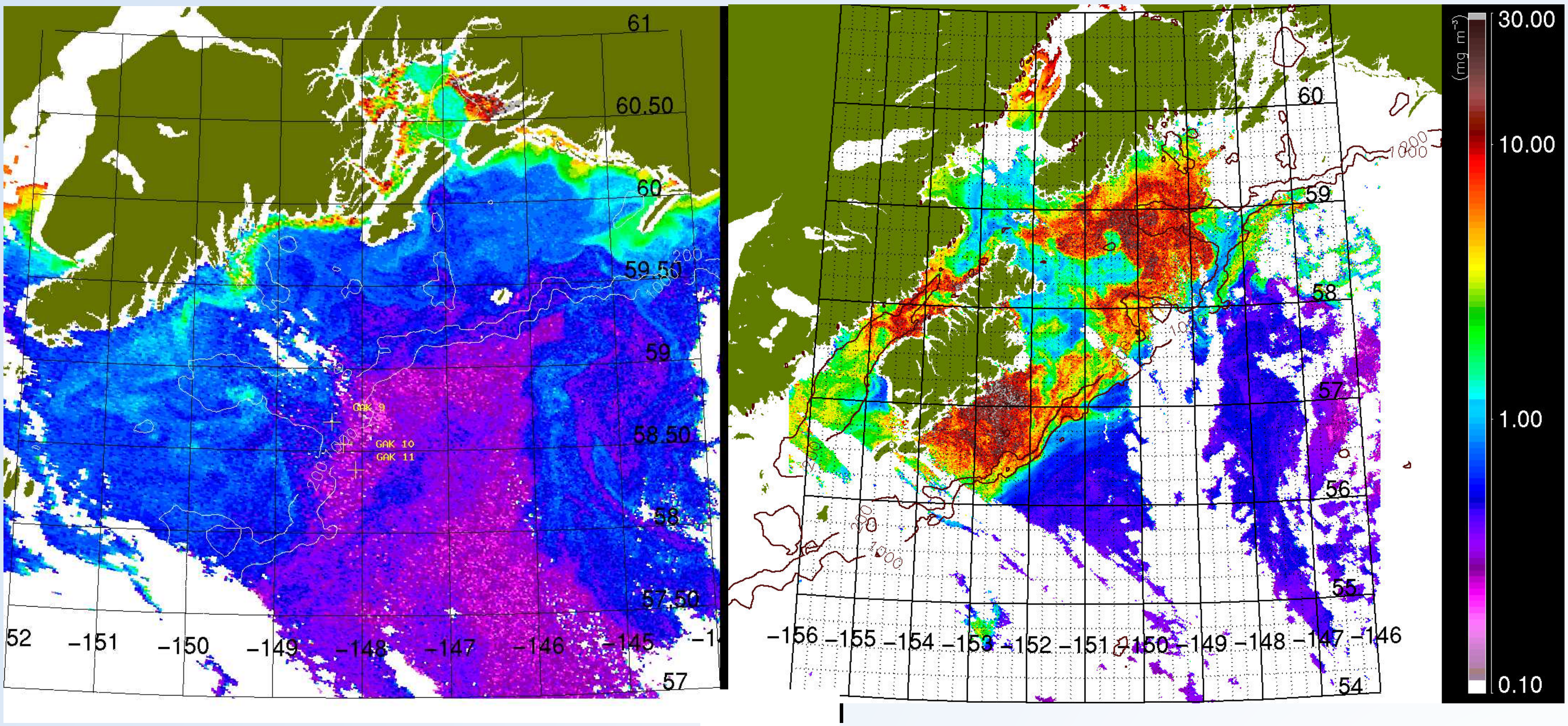


Emerging Diapause | Feeding & Growth | Entering Diapause

(K. Coyle)

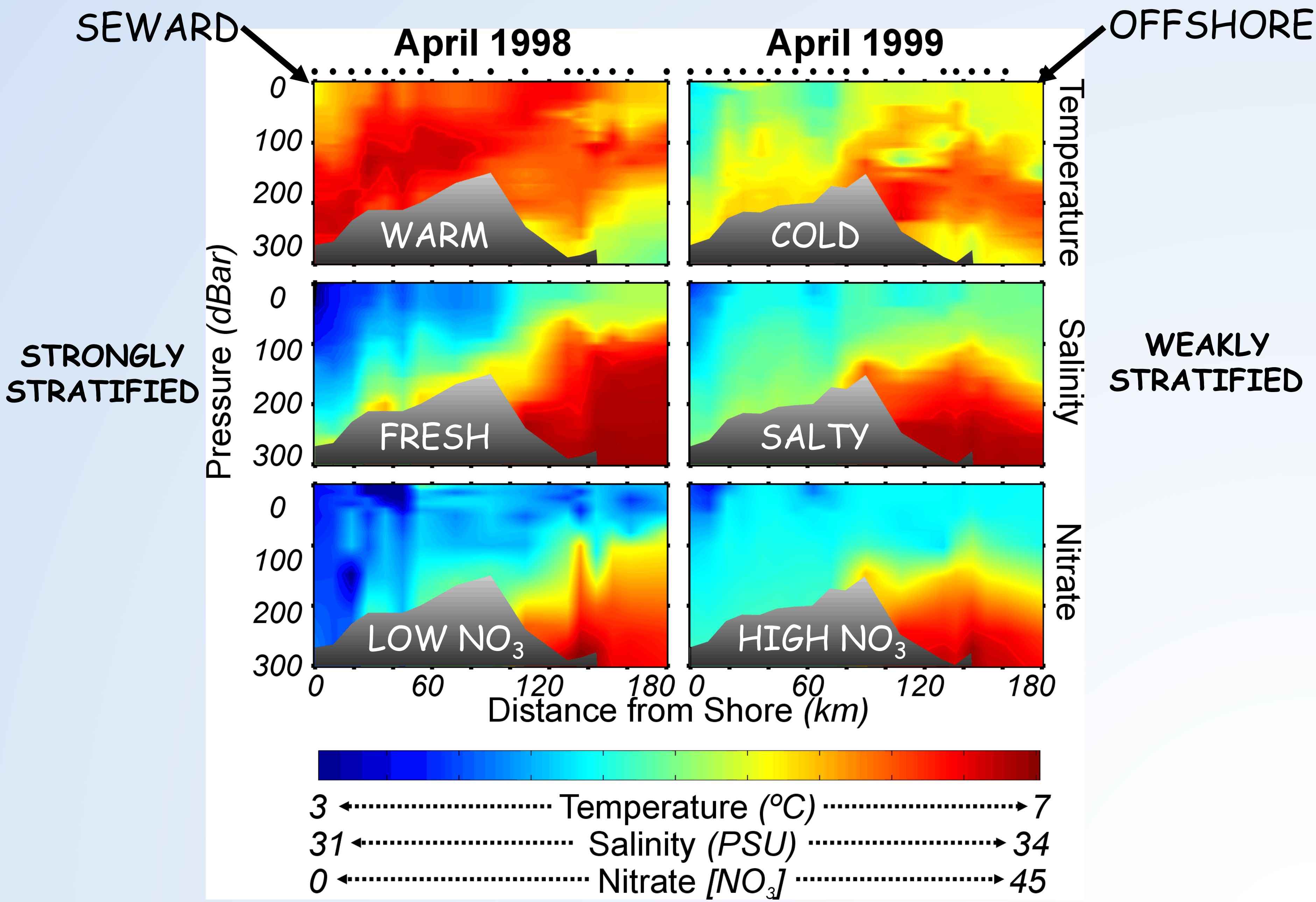
April 1, 2003

May 16, 2003

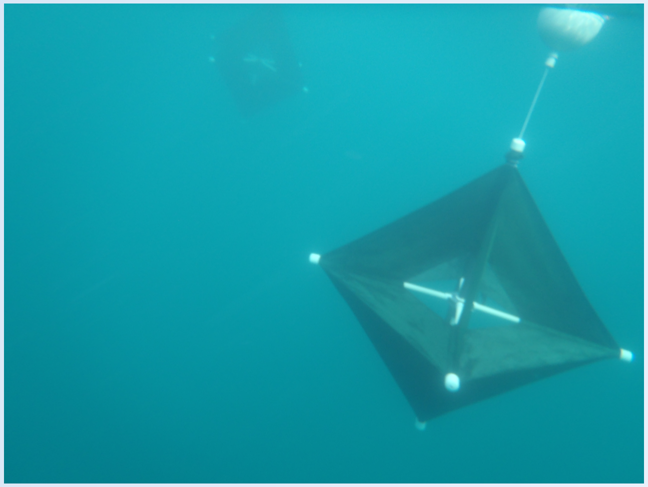


Primary production starts on the inner shelf earlier (0.5 – 1 month) than the mid- and outer shelf due to different stratifying mechanisms.

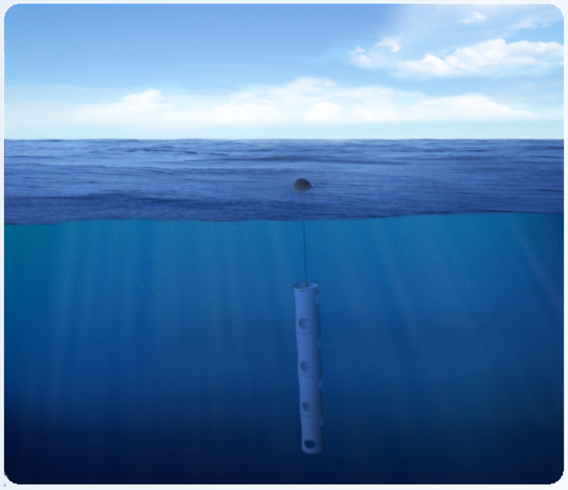
Example of interannual variability



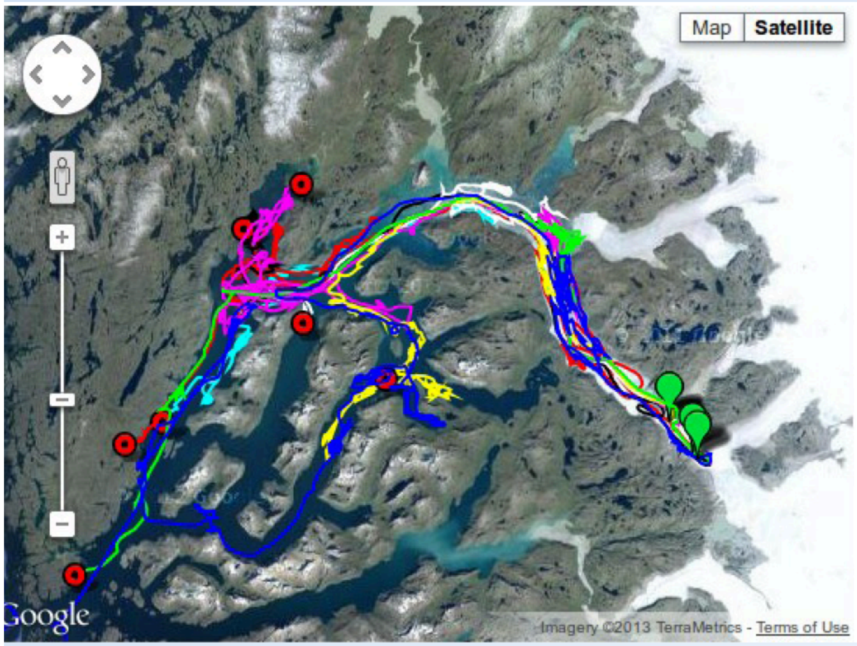
Drifters: In order to define the circulation, temperature and salinity structure in a large fjord system on the west coast of Greenland, we have deployed several ice-strengthened drifters equipped with Seabird microCAT CTDs, where drifters measure salinity at 0, 7, and 15 m depth.

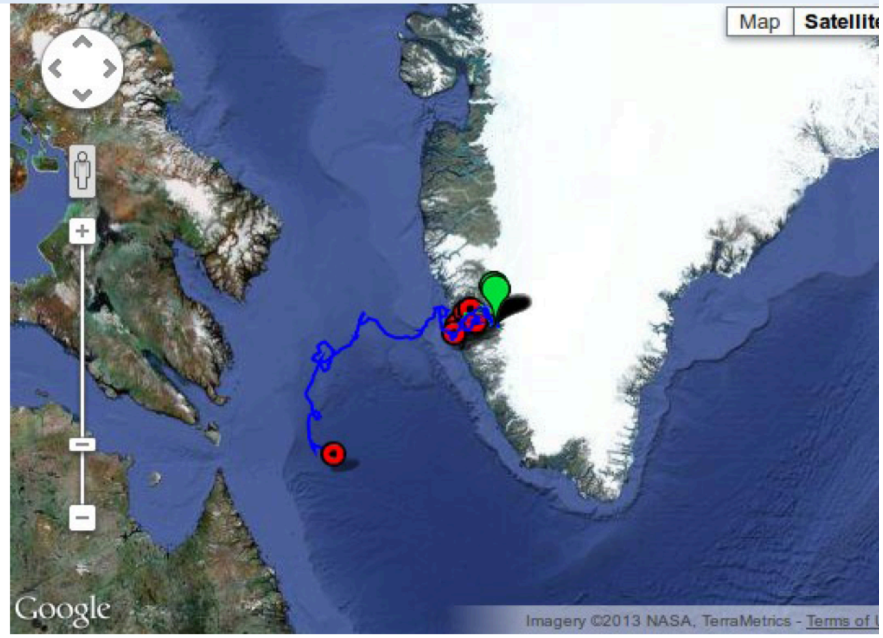


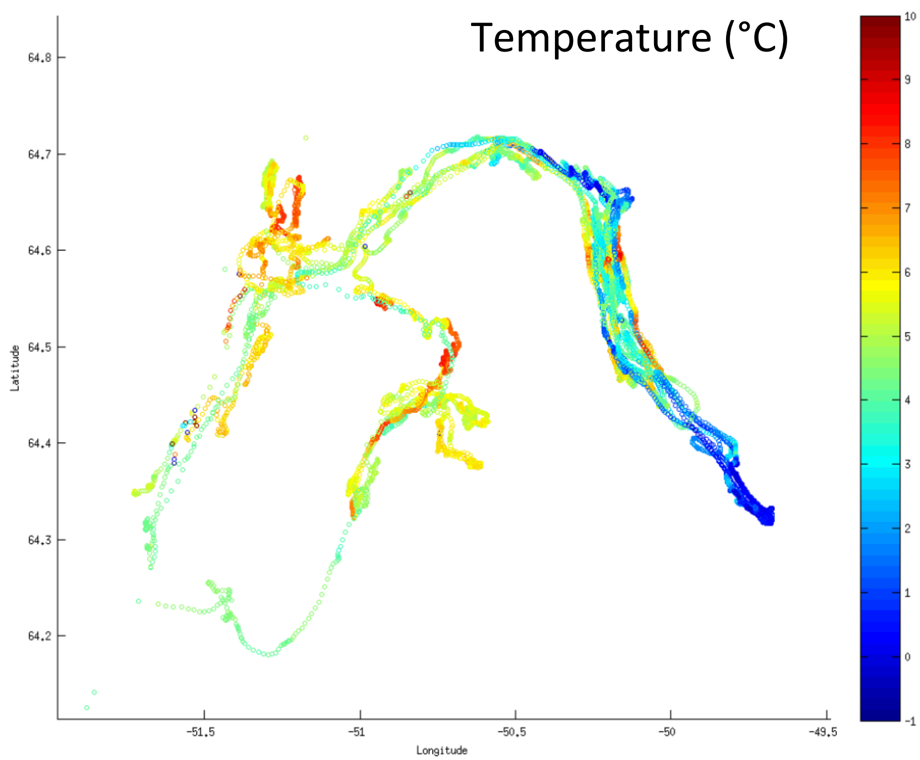
Microstar SST-Iridium surface drifter

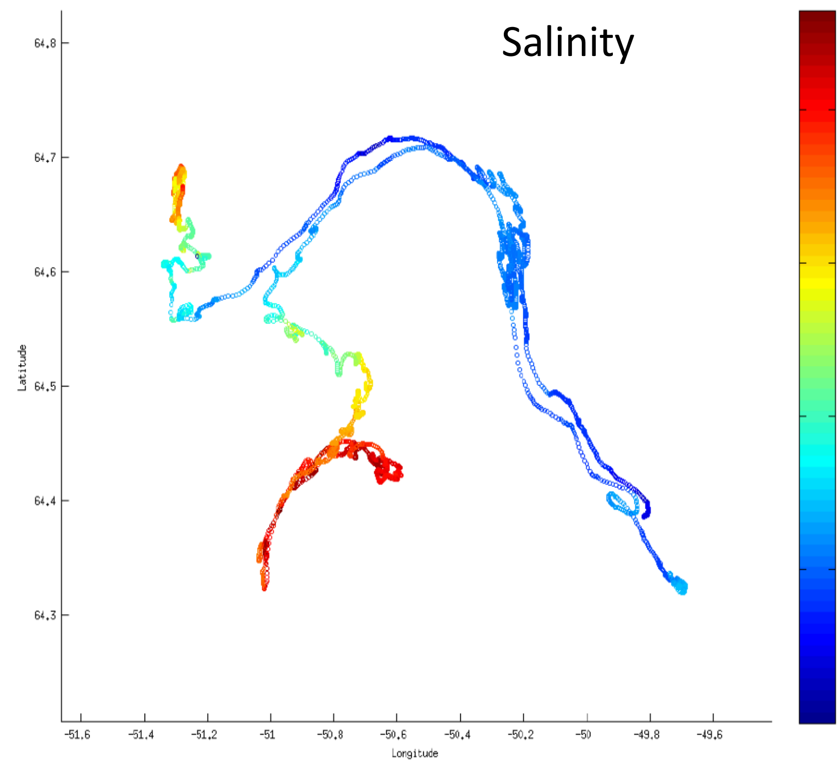


20-m drogued CTD-chain-Iridium drifter


Map
Satellite
Google
Imagery ©2013 TerraMetrics - Terms of Use


Map
Google
Imagery ©2013 NASA, TerraMetrics


Temperature (°C)
Latitude
Longitude
64.8
64.7
64.6
64.5
64.4
64.3
64.2
-51.5
-51
-50.5
-50
-49.5
10
9
8
7
6
5
4
3
2
1
0
-1


Salinity
Latitude
Longitude
64.8
64.7
64.6
64.5
64.4
64.3
-51.6
-51.4
-51.2
-51
-50.8
-50.6
-50.4
-50.2
-50
-49.8
-49.6
20
15
10
5
0

Acrobat Towed Vehicle

-real-time data feed through faired, small diameter Kevlar cable

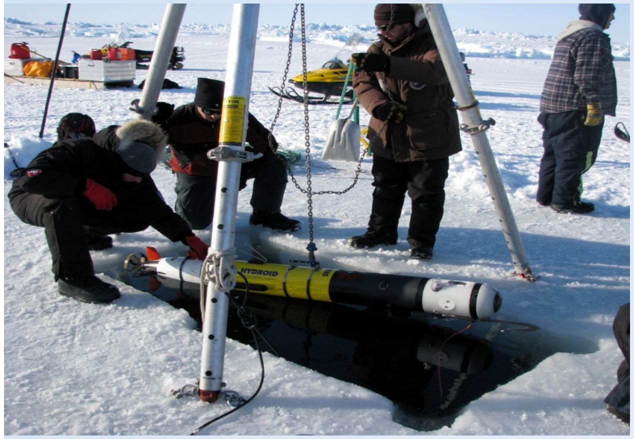
-large data bandwidth via Ethernet

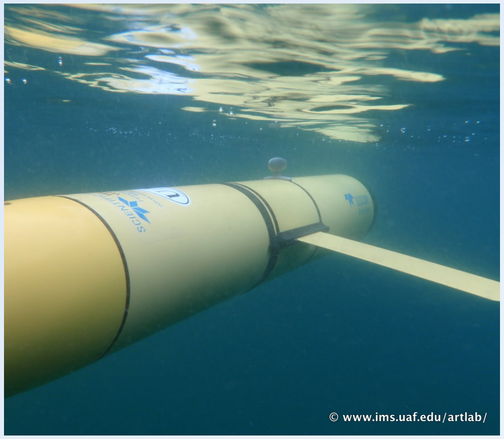
-small and easy to operate and deploy/recover from small vessels even Zodiac

-6 knot tow speed generates high-resolution data over large areas

-we instrumented the Acrobat with a 16 Hz Seabird FastCat CTD and 8 Hz Wetlabs Eco Puck

Autonomous Underwater Vehicles (AUVs)





Left: Deploying the REMUS AUV through coastal sea ice offshore of Barrow, Alaska. **Middle:** Webb Slocum glider nearing the surface in Auke Bay, Alaska, 2010 . **Right:** The Exocetus Costal Glider being field tested in extremely stratified conditions in Resurrection Bay, Seward, Alaska, 2012

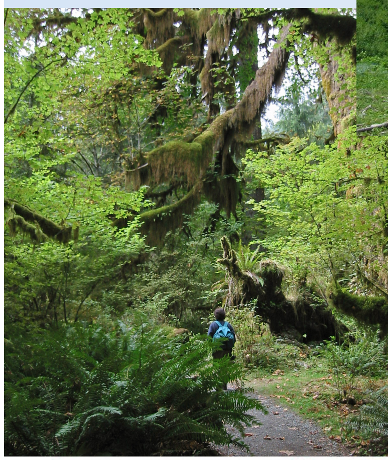
Gliders can sample an area for up to 4 months autonomously.

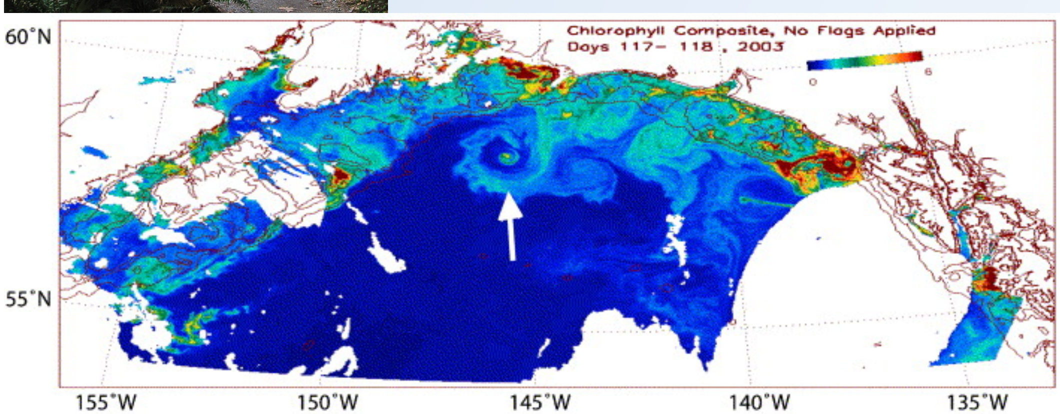
The Coastal Glider can handle extremely stratified locations.

Real-time data via Iridium, which enables adaptive sampling.

Development need for complete long-term autonomous sampling under ice

Thank you ☺




Chlorophyll Composite, No Flags Applied
Days 117- 118 , 2003
0
6
60°N
55°N
155°W
150°W
145°W
140°W
135°W